Log for North Pole Educational Expedition 2003

Background:
Senator Debbie Stabenow (D-MI) sent a letter to NASA HQ, Mr O'Keefe, requesting NASA-GSFC and myself in particular to provide webcasts in the High Arctic Polar region, including at the Russian North Pole Ice Station in April, 2003. This request was in the interests of publicizing a unique educational outreach initiative by schools in her state. Because a Native American tribal college (Bay Mills Community College) was involved NASA Code N, Minority Programs deemed that this request ought to be funded and they solicited approval from Code M in order to enable the use of the TDRSS-F1 satellite. This 20-year old satellite is uniquely able to point a 16-ft dish antenna at the exact Poles for several hours each day and thus to enable a high speed Internet connection to a portable terminal on the floating ice. NASA HQ PAO sent a response to the Senator indicating that indeed GSFC would attempt to honor her request on a best effort basis, given the very little time allowed to prepare. $40k was obtained from Code N based on the educational outreach value of this effort and the fact that there was sufficient interest from NASA science. I rushed international travel orders through in 8 hours with a lot of cooperation from GSFC and NASA HQ, and obtained all clearances for country and RF transmissions, as required including from FAA, Code 450, and Norway.

The Educational Outreach concept was for college students and teachers to work in the field with scientists doing research that followed NASA guidelines in order to inspire the next generation of NASA explorers as only NASA can. There were two areas of investigation addressed in this expedition. The first effort involved an extensive ice thickness survey of a 3km area and the second was a series of atmospheric measurements done both near the geographic Pole and at 78N in the Longyearbyen, Norway area.

The Ice thickness survey was done under the direction of the Cold Regions Research and Engineering Labs (CRREL), with tools and expert consultants they provided, coupled with the on site direction of Dr Rhett Herman, Geophyscist from Radford University. Dr Herman brought his own EM 31 device identical to the one provided by CRREL, which he uses routinely to do similar work. The survey entailed drilling numerous holes through the ice across a 3km line and making hundreds of snow cover thickness measurements every 5 meters. The idea was to characterize the floe well enough to correlate with other similar data gathered in the lower latitude arctic ocean during the Spring 2003 by CRREL. In addition, having the floe characterized so well it was intended to place at least one Buoy in the thickest area, which would then monitor the changes over a full year. The University of Washington, Dr James Morison, wanted to correlate the buoy's spot data with the larger floe and thereafter infer data on how the larger floe changes by extrapolating the buoy data. One means of gathering more ice thickness measurement data was to use the two EM 31 electromagnetic induction devices that the team brought. These devices have been used successfully in the Beauford Sea at 70N – 73N latitude and if calibrated properly by the actual drilled holes, they can produce a readout every 5 meters relatively quickly. Dr Herman had a secondary objective to collect readings every 2 meters over a 100m x 100m grid. With these he intended to demonstrate that a two-dimensional image could be produced of the underside of the ice in that grid.

The arrangement for logistics involved NASA providing some of the funding required for the charter flight, while BMCC provided most of it. The arrangement was for NASA personnel to provide the scientific expertise, any logistical/safety support needed beyond what the Russian hosts were to provide, and the webcast engineering and production team. The total group consisted of 8 persons from BMCC and the rest were selected by NASA to cover the above commitments.

My group was limited to 25 hours on the Ice floe due to the logistics dictated by chartered flights available from the Russian non-profit organization, Centre Pole. This charter flight originated in Longyearbyen, Norway (78N x 15E). It included an An74 Russian jet that could take 45 passengers for the main flights to/from the Borneo-2 Floating Ice Station at 89+N x 92E. In this case it took the 25 passengers in my group and more than 14 large boxes of equipment. A Mi-8 Russian helicopter was then used to first survey the floe near the runway and pick out the center location for the survey grid. Thereafter this helicopter was used to ferry persons to/from another semi-permanent camp called Borneo-1 (6 km distant), which had broken off the main floe, but which contained most of the accommodations.

The second scientific endeavor was centered around various atmospheric measurements including those done by the GLOBE program using student observations. Brent Holben, NASA scientist from GSFC Code 924 led these efforts as an extension of his Aeronet network of observing sites. Under Holben's direction the students and professors from four different colleges/universities and several secondary schools monitored ozone, aerosols, arctic haze, pollutants, clouds, and more. Measurements were made both at Borneo-2 and later for several days in Longyearbyen (LYR).

The logistics of traveling to the geographic North Pole are never easy nor risk-free. In my previous three trips we used three different logistical approaches all involving Twin Otter aircraft based in Resolute Bay Canada (75N x 94W). This approach works fine for perhaps 6 persons and some equipment totaling around 1400lbs together. Conversely, the Russian approach was able to handle 25 persons and about 3000 lbs of equipment with room to spare. Cost-wise the twin otter charters each cost $45K and the Russian charter $60k. Furthermore, the Russian Charter cost included providing full Arctic Extreme Cold Weather Gear (Parka, Wind Pants, Boots, and Gloves) for every person, valued at $15k total, which they each kept. Hence, the Russians were the only option for this large an endeavor, but for cost reasons also, they were well worth dealing with.

Dealing with the Russians entails a few additional logistical twists that complicate matters. First the language barrier and the time zone delta slows down communications for advanced planning. As such we dealt through a Point of Contact, Mr Misha Malakhov, who traveled to the USA to promote Centre Pole's latest endeavor, the first ice station to be manned year-round, the North Pole Drifting Station (NPDS). However, it was not clear that deals made with Mr Malakhov were not necessarily sanctioned by Centre Pole, until we arrived on the scene. Then too, the Russians are supporting a number of independent activities during the month of April and as such that are constantly juggling their logistics

as may be necessary. Although their primary activities are scheduled and generally held to, weather-permitting, any secondary logistics are subject to and likely to change without notice.

Description of Field Activities as conducted:
Prior to deploying from LYR the Centre Pole issued Arctic Parkas, wind pants, boots and gloves to every person on our team, which were theirs to keep. These were above and beyond the essential cold weather (ECW) gear that each person already had to bring, so each person then had the option of which set of ECW they would use.

In this group the leader, myself, was the only one who had ever been to the North Pole, yet there were intentionally eight all together with Polar survival experience. We were to have a Russian guide/interpreter meet us in LYR and travel with us, but in LYR we were told that he was already on Borneo and would meet us there. This person was to be Mr. Malakhov's son, Misha Junior, but as it happened, he never showed up.

The 3-hour flight between LYR and Borneo-2 flew over the Pole and was uneventful otherwise. Landing on the floating sea ice runway was no more difficult than I have experienced with the twin otters and in my opinion this is the ideal way to travel to the North Pole. Equipment was off loaded and at that point the Russian leader on the scene indicated that it was not possible to find a large piece of sea ice at the Borneo-1 camp site, since the floe had broken up and that camp was now 6km away on a small section. He recommended that we stay at Borneo-2, where the runway was located and do our survey there. His offer was to fly us over the floe in the Mi-8 to pick out the best section to survey and then to set up our operations in the middle of that section. He would then return in 2 hours with a ski-doo and would shuttle persons to and from the Main Camp for food during the day, since it was only a 10-minute helo ride away. There was a warming tent located on the runway where several Russians were based and we could use this if necessary in the event of any emergency or bad weather. The weather however, was excellent the entire time we were in the area. Therefore, we loaded the helo and surveyed the floe from above. I depended on Mr Austin Kovacs, the experienced CRREL representative with us, who was to supervise the data collection during the Ice thickness survey, to sit in the cockpit and locate a suitable survey section from above. Upon landing in the center of that section we off-loaded and the helo departed. It returned 4 hours later with the Ski-doo and food, which was later than we had expected.

Our arrangement with the Russians was that they would provide polar bear protection and ski-doos. Nevertheless, I enlisted six persons to be on my team specifically for safety and polar experience reasons. These included two Norwegians from LYR and two Antarctic Riggers fresh from working for NSF at McMurdo and South Pole, October 2002 through February, 2003. In addition we had one Arctic ranger and one eagle scout among the educators; not to mention myself, an experience polar expedition leader. Between them they had four polar bear guns, which we had rented in LYR, and they basically watched out for all the safety factors, including personal fatigue, frostbite warning signs, personal discomfort from the cold, and such. Regarding personal safety, I at no time heard of any extreme discomfort or distress, although we were on the ice continuously for about 12

hours before we took the first break in the Russian warming tent. Our plan was to work straight through for 24 hours and then leave, since the Russian logistics dictated that the only flight out for 25 persons would be the following day. Thereafter the next return flight would be five days later and it was already almost fully booked. We all agreed to this schedule and were well prepared for it, but it would have been much easier had the Russians kept their agreement to bring people to the Borneo-1 camp for meals. This turned out to be too much to expect, since they did several helo trips for the survey from above, the ski-doo and food delivery, and returning two of our party with the ailing EM 31 devices to the main camp to attempt repairs. We found out later that they were very low on fuel and were trying to conserve flights by waiting until they could combine requirements into a single trip. Hence, the Russians felt they had done enough and barring an emergency, they elected to not return to bring our party back to the main camp for a second meal. As such, we never got the EM 31s back into the field and so a number of persons were left with nothing much to do for the remaining 12 hours. These persons were taken to the warming tent earlier than planned, but not until the webcast was completed.

Austin Kovacs initiated the layout of the grid as per CRREL directions and his own experience and the two teams arranged in advance accompanied him. After establishing the procedure with his team, a second team left the central tent in the opposite direction and together they laid out an ~3km line. Every 5 meters they made snow cover thickness measurements (583 in all). The EM 31 teams let the EM 31s cold soak initially to stabilize and then powered them On, as was the plan. However, with this approach the readout devices never did stabilize. We suspected Cold problems due to the –30C ambient temperature, so eventually Dr Herman and Mr Dickinson took the devices back to Borneo 1 in the helo that had brought the Ski-doo and food supplies. Unfortunately, they never returned due to Russian refusal to fly the helo back again until it was time to go. Meanwhile, Austin and I started the hole drilling activities following the 3 km line with a hole every 30m. All the data was recorded in real time by dedicated persons. I modified Austin's drilling technique whereby we would pull the drill out every foot or so, as it was spinning in the forward direction. This pulled the slush out of the hole as opposed to augering the bit in and having to drive it out in reverse, which left the hole full of slush. I further set up two drills with separate extension cords running one at a time off a single generator. Each drill was a Porter Cable #635 with T-handle ($265 each, one new from BMCC and one used from Austin Kovacs). One drill was loaded with 2 meters of flites and the other with 4 meters of flites. Alan or John, each well over 6-ft tall were able to drive the flites in with that pumping action and quickly change out drills to cover 4 meters in about 2 minutes. After that if necessary we would add a flite or two, but not too often as the average depth was 3.16 meters. Later I introduced another measurement not planned in advance. We measured the distance from the white surface to the surface of the water inside each drilled hole. This water level would be a consistent baseline, which we felt would be of use in the data analysis and it really turned out to be a good idea.

In parallel, Dr Holben was setting up his Aeronet instruments, along with Ivan Forde and his pollutant monitors. A number of BMCC teachers/students were involved in those activities as a learning experience.

In parallel as well, Mr Dave Beverley set up the TILT inside the special tent we had brought for that purpose and started warming up the electronics with heating pads powered from two of our four 1kw generators. I set up the antenna and discovered that the RF connector had separated from the phased array when its conductive glue froze. I attempted to make a repair, but was advised by Mr Beverley that the signal was fine, not to play with it. This later came back to haunt us, since the webcast started fine, but after a short time this connector ground separated enough to terminate our transmission, without us having a link to the folks in CONUS to know that they had lost our signal. We only found out two days later. Our three Iridium phones worked fine for transmitting, but did not alert us if/when calls were received. We had two commercial Iridium phones that receive incoming calls (the DOD phone did not), but Dave was only using the DoD phone. The other was in his tent and he did not realize it was any different, so he did not expect to get any incoming calls. As such we did not realize that our initial audience had lost our signal, even though they were trying to call us. Mr Beverley did not bring up the chat session because the signal was weak and he dedicated the bandwidth to the uplink. We actually retained RF lock, but data lock was unconfirmed. We thought that this was due to multipathing at the very low elevation angles. However, in hindsight, we now realize that the weak signal was totally due to the frozen antenna connector separating from the ground plane. We had been working for 7 hours on the Ice, before conducting this first webcast. Once it started, we were extremely busy pulling together the webcast speakers. We knew our window was considerably shortened by our actual location on the far (Siberian) side of the Pole opposite the TDRS-F1. The actual usable TDRS-F1 window was over 3 hours long not considering multipath interference, which we could not isolate. We may have been experiencing more multi-path interference than usual due to this location, but most probably our intermittent technical difficulties were due to the poor performance of the antenna with the loose RF connector. In hindsight, I should have heated up the joint and attempted to remake this connection, but was acting under the mis-information that it was good enough and not worth risking loss of signal.

Dave terminated the webcast after about 35 minutes, when he felt we had lost the signal. It is not clear what he was basing this on, as we still had another hour of solid window left, but the antenna performance would have had to improve to get it. As we packed up the gear the antenna connector fell off and I had to do an extensive repair on it once we returned to LYR. Given the repair, however, it worked extremely well for the next webcast. The fix was far superior to the original design, using screws and solder in place of the conductive glue, which froze at these temperatures.

After 10 hours, we had completed half of the planned activities and yet we still did not have any working EM 31 devices. Nevertheless it was clear that we had characterized this floe as well as if we had had three times as many measurements. The data is attached and we were able to clearly show where the optimal locations were to place buoys. As it turned out, the University of Washington did review our data with us at the Borneo-1 camp and took a set with them. Then they used that data to locate two buoys on the Runway floe, so the survey did accomplished another important objective. Given that the EM 31 devices were both out of service and unlikely to return, we were unable to conduct the 100m x

100m 2-dimensional grid that was a special project of the Radford group and the George Mason statistical team, and a second order scientific objective.

In addition Brent Holben had completed his atmospheric measurements and Ivan's monitoring device had also obtained enough data. So, that effort was deemed complete and the workers were ready to do something else or to rest. The original plan was to layout additional lines across the main 3km line, but this was not a critical objective and resting first was in order for most of us.

We then had some people who were without a job to do for the second half of the day and we began to ride them over to the warming tent a mile from the center of our survey grid. This presented a new problem in that idleness causes some level of discontent. Those who were gathering in the warming tent were now getting hungry and tired and looking to lie on the cold floor to rest. (Never lie on a ice floor to stay warm. You'll just get colder.) This was not an issue as long as we were very busy. The Russians in an adjacent tent were on their own break and sleeping, so they were not much help getting in touch with the main camp. We were able to get some water from them and that was about all. We had left messages for our Russian contact, Daniil back in LYR, using our Iridium phones, but he had not as yet been able to get in touch with the Russians on the Borneo-1 camp. Once we had all of our people in the tent we were ready to move back to the main camp, but the word from the Russians was that they did not want to return until the appointed hour (about 10 hours later), unless we had an emergency. If we had our Russian guide as contracted, we would have understood the technical problem the Russians were having. They were very low on fuel and were conserving the fuel they had by combining any essential helicopter flights. A plane was due to leave Siberia with more fuel in a couple days, but they could not allow themselves to run out in the meantime. The scientists who followed us had a larger problem waiting in the warming tent for the helicopter flights until the refueling plane actually left Siberia.

With people singing songs and chit chatting in the warming tent, I took three others and we went back out to complete the hole drilling across the remaining surveyed area, so that we could take advantage of this additional work that had been done earlier. In about 2.5 hours we drilled another 14 holes and made both snow thickness and freeboard measurements to correlate with the surface measurements the layout teams had made. As we finished the Russian helicopter was heading over to pick up our entire team and return deliver us to the main campsite 6 km away. I found out later that the only way they decided to sent the helo in early was because Daniil had told them it was an emergency. Nothing else, eg our contractual arrangements or our realtime requests had made any difference to them at that time. They felt they had used up the allotted help time for our team and they wanted to conserve fuel. In actuality, we had no serious emergencies and only some growing discomfort as people were unable to rest on the cold floor. Those of us who continued drilling would have continued to expand the measurement area even more had the helicopter not been seen on its way.

We arrived at the Borneo-1 main camp about 5 hours prior to our departure time and we all had some hot "add water and stir" noodle soup. I met Andy Heiberg, University of

Washington and with Austin Kovacs, we presented our data to him and left him a copy. Clearly we had fully characterized the floe to a point where he knew two locations to place buoys and that is what his team eventually did.

We had further contracted for the Russians to fly us to the exact Geographic Pole at some point in this 25-hour period and this was the first opportunity. Our group almost unanimously voted to fly the 115km each way (~ 2-hour round trip) if possible, rather than to spend these last 4 hours sleeping. Yet, the Russians would not accommodate us due to two problems they were having. First, they were low on fuel, since one scheduled delivery never made it to the camp. Second, they were having Navigation problems apparently due to what they called electrical storms, so they were afraid that they would be wandering about for longer than necessary and might miss the return flight the was coming on time. We believe that the GPS onboard their Mi-8 was "frozen" and not working properly. We had to abandon this low priority but nevertheless highly desirable goal and we sat out the last couple hours in various activities. Some slept and some walked all around this small floe photographing the expanding leads with boards over them for bridges etc. Clearly, this floe would never have met our scientific objectives nor those of the U of WA team and CRREL either.

We were flown back to the runway in time to gather up our equipment and load it into the An74, which returned right on time as we watched from the warming tent area. The flight home was a bit shorter, since the AN74 did not fly over the Pole. We left on time and arrived in LYR on time. All in all I would definitely work with the Russians again, but would be sure to take a Russian-speaking person on my team. Next time I would deal with **Leonid Bogdanov**, General Director of Arctic & Antarctic Research Institute (www.polus.org 095 436 2134, 095 436 4963, Fax 095 436 4926), since we now know that he is the direct contact for Centre Pole. There have been some changes in management at Centre Pole this past year and all those who have worked with them say the same things. It is too difficult to get a solid commitment that will be executed as planned. You must accept some logistical risks. The Russian aircraft were interesting. The AN74 jet is superb and nothing else can match it for this job. The Mi-8 helos are very old and remind me of the C-130s that the US Navy used to fly for NSF to/from Antarctica. They keep them flying even with various anomalies. For the short hops we were doing it was not an issue. They can land on a dime any time they need to and the issues were not life threatening. The worse situation was depending on their GPS for any long flights, which at this time were not reliable and this is the main reason we abandoned the 115km ride to the Geographic Pole. Again flying them as we did around the floe area used visual navigation effectively. Finally, the cost with the Russians was so much less than with the Canadians that the logistical risks are probably worth taking, as long as you use the extra payload carrying capability and some of the saved money to better take care of yourselves once on the Ice.

Events in Longyearbyen:
Our first priority upon arrival in LYR was to sort out all our gear and ensure that each person had their own items. We had no physical injuries among our group and all of us seemed extremely pleased with the experience. I asked who would do it again and everyone who heard the questions answered in the affirmative. We were able to return the rented guns in time before that shop closed. The University Centre of Norway on Svalbard (UNIS) sent a van to assist us traveling between the airport and the various accommodations in town 4 km away. Many were staying in an apartment provided by UNIS for merely the cleaning cost, but it was too crowded for all 25 of us, so those who had per diem were able to rent rooms in the various hotels and guest houses at $175 to $200 per night. Doubling up reduced the cost and yet there were only a few rooms available and even then they were only available for some nights, so those persons had to move around.

The following day we rented AWD vehicles and met with Boerre Pedersen the Svalsat Station Manager, who I had just taken to the Pole. Boerre had experience with the Arctic conditions we faced and he had never been to the Pole. He was very helpful on our trip and he was also very helpful after with a tour of the Svalsat ground station. We first went to a local shop and repaired our antenna. Then, we used his truck to haul our equipment for the second webcast up to the plateau where his antenna farm was located. Note that we had to have a TDRS downlink for the normal software to transmit, so prior to the TDRS window for LYR we had to bypass that software to do our RF interference tests. We decided that we were transmitting too loudly for them and although we could still transmit between pass supports, we relocated to the fjord at the foot of this plateau. There we had absolutely no RFI problems with their antennas, so we were able to conduct the second webcast at the planned time. The TDRS-F1 window at LYR was about 9 hours each day. We picked an ideal location on the shore of the ice-filled fjord with spectacular back drop of snow-covered hills, and we did a superb webcast. It started right on time and went without a hitch. Everyone present was able to explain what they were doing from a science perspective as well as to say hello to the schools back home.

Brent Holben spent most of his time in LYR at the University and established some locations for his follow-up team to place more of his Aeronet instruments. The GLOBE teachers conducted their GLOBE experiments and reported on them. The Radford team diagnosed the technical problems with both EM 31s and found a damaged component in the older unit that was due to shipping. They were able to get this repaired back in Virginia, since it was covered by the UPS insurance. The brand new EM 31 problem did, however, seem to be related to the cold soaking prior to turn-on. Given another day in the field this unit would have been warmed appropriately using chemical heaters in strategic locations, but we never got that chance. Still Radford felt that failure was just as educational for their two Physics/Earth Science majors and well worth the experience. Their comment, “We learned from our failures. I think it's fine for people to know that things do go wrong in the field, and then we fix those things and move on.”

Packing required an entire day for me and one or two other persons. Equipment was sorted, packed, and left in the storage area at the airport. We left at 0440 on Saturday morning, one week after we had arrived. As we had done on our outbound flights, we took

most of our equipment as excess luggage, not as cargo, so that it would travel with us and did not get left and any airport. This had worked perfectly on the outbound flights and in fact we were not charged for any excess or oversize pieces on those flights. Conversely on the return flights we had to pay $416 for the oversize luggage, ie the TILT and the two EM 31s. Yet all the luggage followed us home, except the TILT itself. The baggage person in at Oslo was a girl, who did not get enough help lifting this 200 lb box, so she decided to leave it off that plane. I had to spend all day Sunday at airports locating it and getting it shipped back to BWI a few days later. The other 13 boxes we had taken to the Newark (EWR) airport to avoid flying on the small commuter plane between BWI and EWR, so we unloaded them at EWR on our return and drove them home in two vehicles.

Conclusions:

The expedition was very successful from it's educational goals and successful from its technical and scientific goals. It was also amazingly cost effective and efficient.

Educational Results:

The **Bay Mills Tribal school** objectives were different from those of the other main line schools. Bay Mills wanted to inspire more Native Americans to get a higher education and to believe that they too could get involved and contribute to the developing technologies all around them. They were extremely successful in this regard. Since their return their expedition has been featured in many of their local newpapers and public media, as well as interviews by the NY Times.

Nathan Beelen, teaches High School in the Upper Pennisula, Michigan and says, "My students are excited about doing field science. It does not, however, make much sense to get my students all fired up about doing science in the field if they do not have the opportunity to do it. I would love to be able to take some along on projects like this in the future. I am convinced, from the experience, that they can be a real asset and that they are as capable as anyone else of doing field science. Inspiring students to do this kind of science has never been the problem. Having scientists willing and open to invite me and my students along has been. Access to these individuals is extremely difficult. Tons of useful field science goes on in our neighborhood every day unfortunately it is usually done by scientists, who never think of using local school kids and teachers as willing workers. If the goal of this experience was to inspire students to do field science it was a waste of time, they already want to do it. They are sick of learning out of text books. If the goal of this experience was to prove to the world that you don't have to be a rocket scientist to make a useful contribution to the scientific community than in my mind the project was a success, although I am not sure that has been the focus of the main publicity team or that the scientists on this trip were really paying attention to that. In short, stop asking what NASA and scientists can do for us lowly little teachers and our students and start exploring what we can do for you. Schools around the world have a massive workforce for scientists in the form of their students, this workforce is looking for meaningful, useful scientific endeavors rather than stale textbooks. Are there others out their willing to take the chance at tapping that workforce or was this trip truly a once in a lifetime opportunity?"

Michigan State University, Dean of Engineering, Dr Janie Fouke commented, "NASA has received tremendous positive coverage in the Michigan media as a consequence of our

trip. Not only was there a lot of coverage on campus (and MSU is one of the largest universities in North America!), but the Lansing State Journal (the newspaper in the capitol city), local television stations, and a widely heard business/talk radio station provided substantial coverage. The theme throughout these various interviews is the role that the trip played in stimulating young people to chose science/math/engineering careers. The news coverage pointed to the archived webcasts so that students (and others) could access it and see the excitement for themselves. In addition, at MSU the webcasts were viewed live by students and staff, and the URL for the archived information has been widely disseminated.

As you know, I met with the administrators from UNIS (The University Centre on Svalbard) while we were there. Since MSU has one of the largest Study Abroad programs in the world and since we have an announced goal of 40% of our students participating in a Study Abroad program, this is a priority for me. I have distributed the information about the UNIS program to our Study Abroad staff and faculty. I have also met with our Civil and Environmental department chair to discuss the opportunities that exist there. This department is the best link for us in the College of Engineering because of the Arctic Environmental Technology program and the Arctic Construction program at UNIS. I'll keep you posted as this develops."

Radford University, Dr Rhett Herman, Physics Professor says, "We learned the harder side of science in that things don't always work. My students were used to hearing in class about things that did work, since those are the experiments that I so often cite as proof of something. Also, in general, students are only exposed to lab experiences whose outcomes are just about predestined. At least most well-designed labs are like that.

We also learned a great deal about working in conditions so far removed from our everyday lives here in Radford. And, frankly, in most of the continental United States. My hope now is to find a way back up there, at least for me and the two students I took, in order to get those numbers that we missed the first time around. I did learn to always have backup, especially for our EM-31. One thing that will be hard is to find a second EM-31 to take back up there.

I liked the idea of the survey being broadcast while it's being conducted. That is quite unique. Most times, you only hear/see the results of some survey long after it's finished. But, to see it while it's being done is like medical school, when you go and actually watch surgery being performed in order to learn how to do it yourself. It's all fine and good reading the manuals and seeing the snapshots of surgery, but it's a whole new ballgame to be able to interact/talk (at times) with the surgeon before you lay hands on a patient."

Science Results of Ice Survey:

I regard our survey as scientifically successful since it did accomplish its main objectives.

- We laid out a 3 km transect with 583 snow cover measurements, according to the directions provided to us by CRREL and Austin Kovacs (retired CRREL expert), who supervised this operation on site.
- We drilled many more holes than expected, because we had the time and manpower. We drilled 45 holes across the 3 km transect. The data are archived in great detail on our website under "data results" (see, "http://spioffice.gsfc.nasa.gov/FRIGID2003/north_pole_data.html" use tabs under the graph for details).
- We added a new measurement not suggested by others, but which is proving to add valuable information. This is a measurement of the Freeboard with respect to the total thickness at each

hole. When we found that this ice floe was multi-year and it had multiple layers of ice and snow covers, we added this measurement to help sort out the results later.

The APL scientists from the University of Washington, who arrived as we were leaving were given our data and explanations. As a result they decided to place several instrument packages equipped with scientific buoys within our surveyed area according to our measurements. According to Andy Heiberg, these included:

PMEL (Sigrid):

- one mass balance buoy in 2.6 meters of ice. This buoy has a thermistor string in the ice, a submerged upward looking sensor that keeps track of bottom ablation/accretion, a mast mounted downward looking sensor that keeps track of the surface ablation/accretion
- one weather station
- two radiometers
- two web cameras

Stanton:

- ocean heat flux buoy

Argos ID's for Sigrid's buoys are:

22206 Weather station
21076 CRREL thermistor buoy with pingers
21077 CRREL thermistor buoy, no pingers
09114 Eppley radiometer buoy
09115 Kip and Zonen radiometer buoy

I don't know the ID for Dr. Stanton's buoy. He may not be using Argos to transfer his data.

These buoys broadcast their ongoing data to polar-orbiting satellites and they are the basis for extrapolating that ongoing buoy data to the larger floe around them. This was the first such detailed ice floe survey this far North in the Arctic Ocean. It followed the same procedures as developed by our CRREL scientists and used in the Beauford Sea routinely. It was a useful extension to their ongoing data set as was the intention. We also learned a great deal about the operation of the newer model EM 31 in the extreme cold, without costing the scientific expeditions anything. We anticipate that this new information will enable future scientific expeditions to be better prepared for dealing with this equipment effectively. BMCC has sold that new EM 31 to CRREL, where it is now undergoing tests in their cold room. CRREL will soon be using it again, with some new additions to preclude the cold problems we experienced with it.

Scientific Results of the Aerosol Measurements:

Brent Holben provided this assessment of the activities he led:

1. Established a sun photometer with the Russian "drifting research station" located at the N. pole. This will provide the first full season of such measurements near the North Pole.
2. Compared performance of various sun photometers for operation in extreme cold.
3. Established the northernmost permanent AERONET site (Spitzbergen, Norway, 78° N) to begin routinely characterizing optical properties of arctic haze (figure available).
4. Made the first measurements at mid IR bands of Aerosol optical depth under arctic haze conditions from the N. pole.

5. Trained four GLOBE teachers for sun photometer measurements and provided them with sun photometers.
6. Four new schools are now collecting GLOBE sun photometer data useful for validation of satellite aerosol retrievals from MODIS and MISR on board Terra and providing a data base for local aerosol characterization as it may relate to pollution and human health.
7. Provided an opportunity for students to take real and vicarious measurements of atmospheric properties via webcasts from Spitzbergen.
8. Established scientific collaboration with UNIS for arctic haze characterization.

Cost Effectiveness and Efficiency:

It is difficult to exaggerate the cost effectiveness of this expedition. 25 persons and tons of cargo were transported through Norway to the North Polar Ice Floe for the chartered cost of typically 6 persons and 200 lbs of cargo. This included awarding every participant a full set of ECW clothing. The typical cost to overnight in Longyearbyen during this high season is $200/night, yet with the help of UNIS most students stayed for nothing in a rented apartment, where a $140 cleaning fee was paid by their grant. They only had to purchase their food and souvenirs. Commercial airline tickets were purchased in advance at about half the cost of a government air fare.

As for Efficiency, we hand carried all the gear we needed and lost nothing. Everything was with us as expected. We drove our excess luggage to/from EWR to avoid the airline transfer delays and constraints of smaller commuter aircraft between BWI and EWR. We left on Saturday and arrived at the North Pole on Monday. We completed the tasks within the 24-hour window and returned to Norway on Tuesday afternoon. Everyone had the opportunities to accomplish their own particular objectives. Eg Brent Holben had plenty of time to arrange for placement of his Aeronet instruments in LYR, Teachers worked with UNIS on future cooperative projects, Austin Kovacs gave a lecture at the UNIS auditorium. We collected B-roll of Glaciers, Sea Ice, and snow cover. We got a tour of the Svalsat Ground stations and established contacts for future projects. Etc.

There were no physical injuries sustained by any of our participants. No major items were lost or destroyed beyond repair. Problems encountered were not enough to preclude accomplishing the key objectives and overcoming as many problems as we did was a good learning experience for all. We anticipate some additional benefits from lessons learned if/when we attempt to do another similar expedition.